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Research Field: Applied Mathematics

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Current Research Overview

Our research aims to understand a wide range of real-world phenomena using mathematical models. In particular, we focus on the phenomenon known as “thermalization”.

Thermalization is something we experience often in daily life—for example, when a hot cup of coffee cools down over time and never spontaneously returns to its original warm state. The key idea here is “irreversibility”. We intuitively know from everyday experience that many natural processes are irreversible. However, at the microscopic scale—where atoms and molecules are governed by “the Schrödinger equation”—the laws of physics are often time-reversal symmetric. That is, each individual particle behaves in a way that, in principle, could be run backward in time. Yet, when a large number of such particles come together, the macroscopic world they form shows clear time asymmetry: we can't "rewind" time.

Analyzing the time evolution of quantum systems made up of many particles—on the order of Avogadro's number—is extremely challenging. To make progress, we often abandon the microscopic details and instead focus on statistically meaningful macroscopic quantities. This approach forms the basis of “statistical mechanics”, which aims to describe systems *after* they have reached thermal equilibrium. However, statistical mechanics alone does not explain *how* thermalization occurs, or *why* time becomes irreversible at the macroscopic level. To address these questions, we need to analyze the time evolution *leading up to* thermal equilibrium.

Interestingly, certain quantum many-body systems with specific mathematical structures are known to be “exactly solvable”—meaning their time evolution can be analyzed analytically. These systems are called “integrable models,” and several concrete examples are known. In our research group, we aim to construct theoretical frameworks that bridge the microscopic and macroscopic worlds, using integrable models whose time evolution can be exactly determined.

Message to Prospective Students

Before entering graduate school, please make sure you have a solid understanding of “linear algebra” and “calculus”, typically covered in the first two years of university. While not strictly required, some background in “quantum mechanics” and “statistical mechanics” will help you start your research more smoothly.